

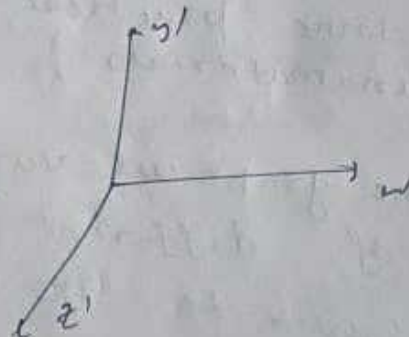
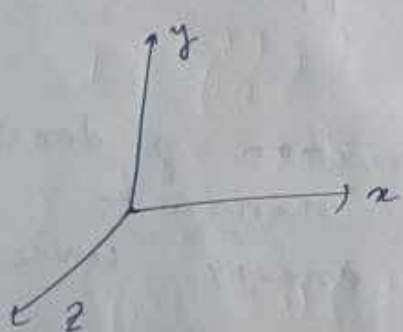
11/04/2023

Mahua Ma'am

- ① What is Lorentz transformation
- ② Derivation of Lorentz transformation
- ③ Direct Lorentz transformation & inverse Lorentz
- ④ What is length contraction
- ⑤ " is time dilation. (Derivation & Related problems)
- ⑥ Variation of mass with velocity.
- ⑦ Equivalence of mass & energy.
- ⑧

Book

Arthur Beiser, Resnick, Gupta Kumar
TAKWIA puranica.



$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$$

$$y' = y$$

$$z' = z - \frac{v_y t}{\sqrt{1 - v^2/c^2}}$$

$$t' = \frac{t - \frac{v}{c^2} x}{\sqrt{1 - v^2/c^2}}$$

Direct L.T

$x =$

$$y = y'$$

$$z = z'$$

$$t =$$

⑧ consequence

→ (i) L

(ii) T

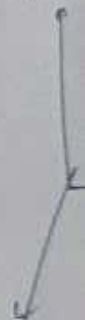
(iii) T

(iv) R

(v) ~~tan~~

⑨ proper

⑩



x

x_2

Time dilation



$$t_1 = \frac{t'_1 + vx'_1/c^2}{\sqrt{1-v^2/c^2}}$$

$$t_2 = \frac{t'_2 + vx'_2/c^2}{\sqrt{1-v^2/c^2}}$$

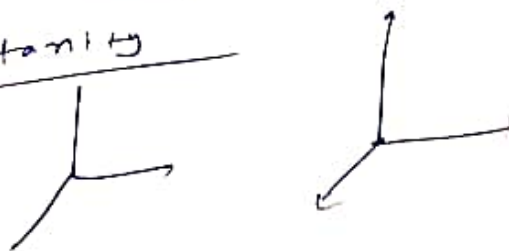
using inverse

$$t_2 - t_1 = \frac{t'_2 - t'_1}{\sqrt{1-v^2/c^2}}$$

$$T_{(R)} = \frac{T_0 \text{ (proper time)}}{\sqrt{1-v^2/c^2}}$$

$$T > T_0$$

Simultaneity



(10) S.T at classical limit Lorentz transformation transform into Galilean transformation.

(11) Relativistic energy show that a mass particle at rest can possess energy.

$$x_2' - x_1' = L_0$$

$$L_0 = \frac{L}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Q) How fast a rocket have to go relative to an observer for its length to be contracted to 99% of its length at rest?

$$\rightarrow L = 99\% L_0$$

$$L = \frac{99}{100} L_0$$

$$\frac{99}{100} L_0 = L_0 \left(\sqrt{1 - \frac{v^2}{c^2}} \right)$$

$$\frac{99}{100} = \sqrt{1 - \frac{v^2}{c^2}}$$

$$1 - \frac{v^2}{c^2} = \left(\frac{99}{100} \right)^2$$

$$1 - \left(\frac{99}{100} \right)^2 = \frac{v^2}{c^2}$$

$$\Rightarrow \frac{100^2 - 99^2}{100^2} = \frac{v^2}{c^2}$$

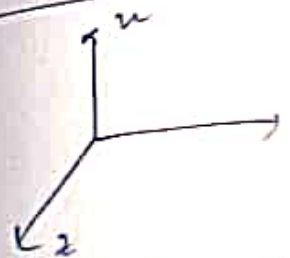
$$\Rightarrow \frac{(100 - 99)(100 + 99)}{100^2} = \frac{v^2}{c^2}$$

$$\Rightarrow \frac{199}{100^2} \times c^2 = v^2$$

$$\Rightarrow v = \sqrt{\frac{199 \times c^2}{100^2}}$$

$$\Rightarrow v = \frac{c}{100} \sqrt{199}$$

Time dilation



$$t_1 = \frac{L}{v}$$

$$t_2 =$$

$$t_2 - t_1 =$$

$$T = \frac{L}{v}$$

$$T = \frac{L}{v}$$

Simultaneity

(10) S.T at transform

(11) S.R particle

in sign of the zeroth component.

So the scalar product is expressed as

$$a^\mu b_\mu = a^\mu b^\mu$$

$$= -a^0 b^0 + a^1 b^1 + a^2 b^2 + a^3 b^3 \longrightarrow (**)$$

The invariant interval Suppose there are two events A, B occurred at $(x_A^0, x_A^1, x_A^2, x_A^3)$ & $(x_B^0, x_B^1, x_B^2, x_B^3)$

The difference is

$$\Delta x^\mu = x_A^\mu - x_B^\mu \longrightarrow (***)$$

This is called the displacement four vector.

The scalar product of Δx^μ with itself is a quantity called interval b/w two events

i.e.

$$(\Delta x^\mu)(\Delta x_\mu) = -(\Delta x^0)^2 + (\Delta x^1)^2 + (\Delta x^2)^2 + (\Delta x^3)^2$$

$$2) \text{ Interval} = -c^2 t^2 + d^2 \longrightarrow (****)$$

$$d^2 = (\Delta x^1)^2 + (\Delta x^2)^2 + (\Delta x^3)^2$$

where

here t is time difference, d is spatial separation.

$$\mathbf{A} = -\nabla\phi$$

Griffiths

M. A

Four vectors

The Lorentz transformation b/w prime and unprime co-ordinates may be expressed in the following form

$$\begin{pmatrix} x' \\ y' \\ z' \\ ct' \end{pmatrix} = \begin{pmatrix} \gamma & 0 & 0 & -\beta\gamma \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\beta\gamma & 0 & 0 & \gamma \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ ct \end{pmatrix} \quad \text{--- (1)}$$

where, $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$

$\beta = \frac{v}{c}$

Now

Renaming the co-ordinates as $ct = x^0, x = x^1, y = x^2, z = x^3$ the matrix can be written as

$$\begin{pmatrix} x^0 \\ x^1 \\ x^2 \\ x^3 \end{pmatrix} = \begin{pmatrix} \gamma & -\gamma\beta & 0 & 0 \\ -\gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x^0 \\ x^1 \\ x^2 \\ x^3 \end{pmatrix} \quad \text{--- (2)}$$

$$x = \frac{x' + vt'}{\sqrt{1 - v^2/c^2}}$$

$$y = y'$$

$$z = z'$$

$$t = \frac{t' + vx'/c^2}{\sqrt{1 - v^2/c^2}}$$

inverse L.T

(8) consequence of Lorentz transformation.

→ (i) Length contraction

(ii) Time dilation

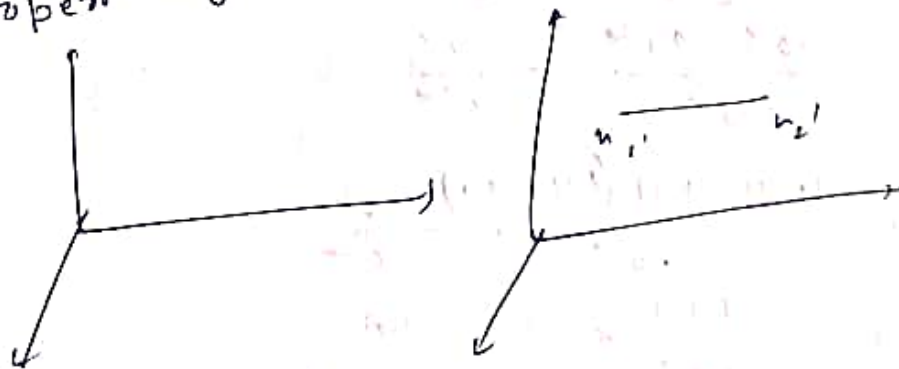
(iii) Twin paradox

(iv) Relativity of simultaneity

(v) ~~time~~

(9) proper length & Relativistic length

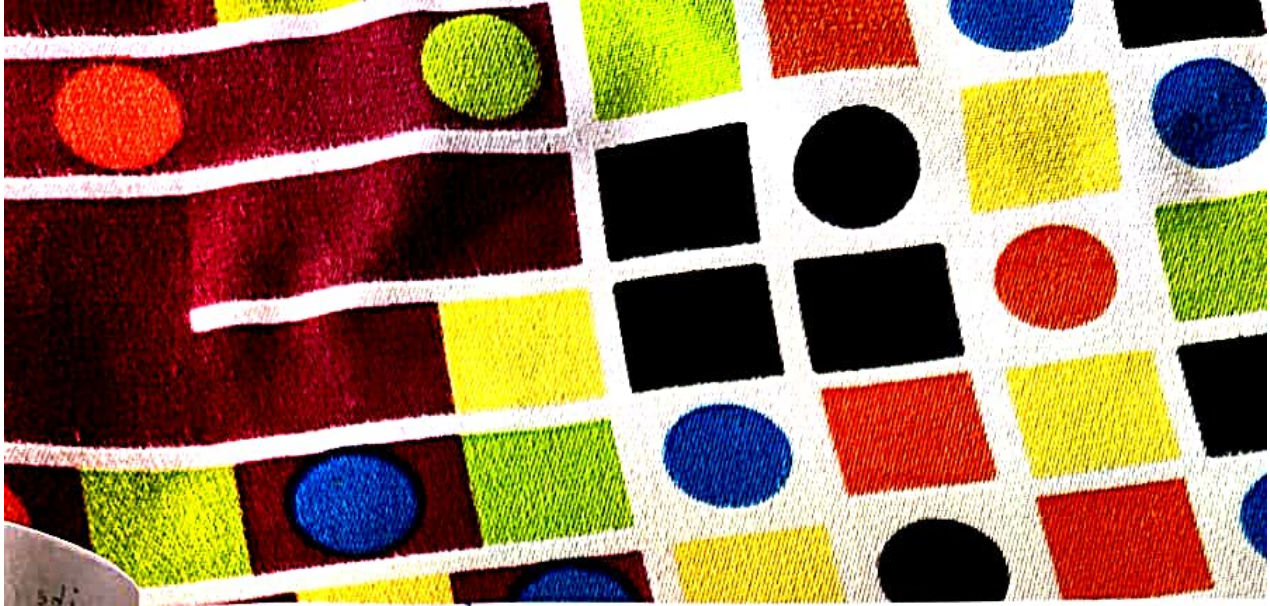
(10)



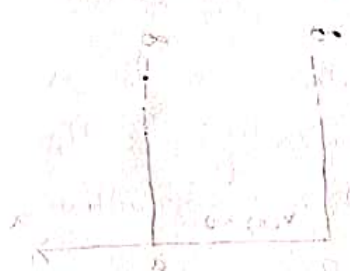
$$x_1' = \frac{x_1 - vt}{\sqrt{1 - v^2/c^2}}$$

$$x_2' = \frac{x_2 - vt}{\sqrt{1 - v^2/c^2}}$$

$$x_2' - x_1' = \frac{x_2 - x_1}{\sqrt{1 - v^2/c^2}}$$



HW Importance of Defect in Nanostructure Material. #2



Defects in nanostructures are of two types: point defects and line defects. Point defects are atoms or molecules missing from the lattice, while line defects are dislocations. Defects can significantly alter the electronic and optical properties of nanostructures. For example, a single defect in a semiconductor nanostructure can act as a trap for electrons, changing its conductivity. In quantum dots, defects can lead to the formation of localized states within the bandgap, which can be used for applications like single-photon sources. Understanding and controlling defects is crucial for the design and optimization of nanostructured materials.

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Density of states.

Show the graphical variation of energy states w.r.t. Energy for bulk, 2D, 1D & 0D.

Degree of freedom

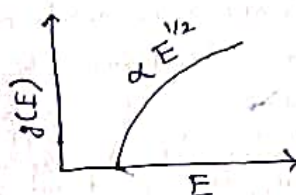
Structure

Density of state

3



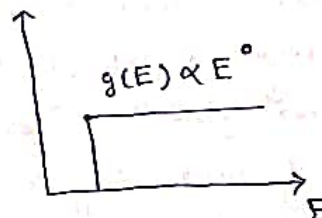
Bulk



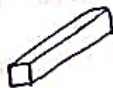
2



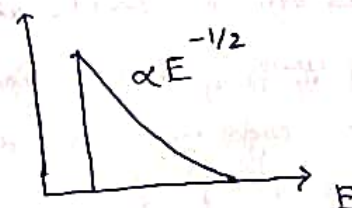
Well



1



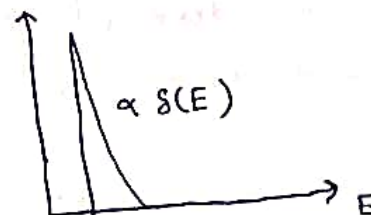
Wire



0



Dot



19/04/25 (N.B maam)

• 3D Nanostructures

These nanostructures have significant dimensions in all 3 directions at nano scale. Though they're considered as nano structures, they have more traditional bulk like

E.g porous materials w nano-pores

A structure where nanoparticles aggregate into
• 3D networks

• Write the key diff. b/w nanoscale & bulk sys?

→ i) Size	1-100 nm	> nm order.
ii) Surface area: vol ⁿ ratio	high	low
iii) Q effect.	✓	✗
iv) Mechanical property	flexible & ductile	brittle
v) Optoelectronic property E.g.	optical & electronic property enhanced (semiconductor behaviour)	Optical & electronic (semiconductor behaviour) properties aren't enhanced at bulk sys. (No change)
vi) Manufacturing & Processing	Lithography self assembly etc.	Casting, molding

$$\Rightarrow (\vec{\nabla} \cdot \vec{D} - f) dv = 0$$

$$\text{if } dv \neq 0$$

$$\therefore \vec{\nabla} \cdot \vec{D} - f = 0$$

$$\boxed{\vec{\nabla} \cdot \vec{D} = f} \text{ proved. } \longrightarrow (a)$$

Let us consider a volume V bounded by surface S in a magnetic medium.

By Gauss theorem

$$\int_S \vec{B} \cdot \vec{dS} = 0$$

Applying Divergence theorem

$$\int_S \vec{B} \cdot \vec{dS} = \int_V (\vec{\nabla} \cdot \vec{B}) \cdot dv$$

$$\therefore \int_V (\vec{\nabla} \cdot \vec{B}) \cdot dv = 0$$

$$\int_V (\vec{\nabla} \cdot \vec{B}) dv = 0$$

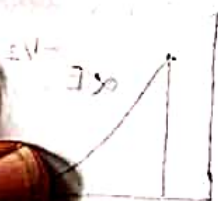
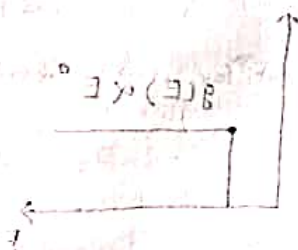
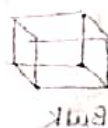
$$\therefore \boxed{\vec{\nabla} \cdot \vec{B} = 0} \longrightarrow (b)$$

Define &

• What are consequences of Quantum Confinement :

A: Quantum confinement is a process where confinement of e^- are done by lowering the dimensions of which effects the electronic state.

↑ E levels
(LUMO energy level)
(HOMO energy level)



Diff. b/w hopping & metallic conductivity.

Hopping conductivity occurs in materials w localized electronic states.

Metallic conductivity occurs in materials w delocalized e^- sea where charge carriers move freely throughout the materials due to large no. of free e^- .

• In materials showing hopping conductivity, the e^- band struc is characterized by a series of localized energy state within band gap.

Band structures are of V.B & C.B partially

• Hopping conductivity is highly temp. dependent w, $\uparrow$ in temp, charge carriers get available thermal E to overcome E barriers, leading to increasing conductivity

In electric metallic conducting Temp. has very less impact

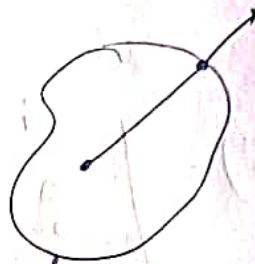
• Here, the mobility of charge carriers is gen. lower compared to metallic conductivity.

$$\begin{aligned}
 i) \quad \vec{\nabla} \cdot \vec{D} &= \rho \\
 ii) \quad \vec{\nabla} \cdot \vec{B} &= 0 \\
 iii) \quad \vec{\nabla} \times \vec{E} &= - \frac{\partial \vec{B}}{\partial t} \\
 iv) \quad \vec{\nabla} \times \vec{H} &= \vec{J} + \frac{\partial \vec{D}}{\partial t}
 \end{aligned}
 \left. \vphantom{\begin{aligned} i) \\ ii) \\ iii) \\ iv) \end{aligned}} \right\} \text{Maxwell eqns}$$

Proof

Let us consider a volume V , bounded by the surface S in a dielectric medium.

By Gauss theorem of electrostatics



$$\int_S \vec{D} \cdot d\vec{S} = Q = \int_V \rho \, dv \quad \text{--- (1)}$$

where $D = \epsilon_0 E$

Q = total charge

ρ = volume element.

Applying Gauss Divergence theorem

$$\int_S \vec{D} \cdot d\vec{S} = \int_V (\vec{\nabla} \cdot \vec{D}) \cdot dv$$

$$\therefore \int_S (\vec{\nabla} \cdot \vec{D}) \cdot dV = Q = \int_V \rho \, dv$$

~~Now~~

Depending on ct , the interval

may be +ve, -ve & 0

i) if $ct^2 > d^2$, the interval is time like, in this case the events take place in a same place

ii) if $ct^2 < d^2$, the interval is ~~the~~ space like and events are simultaneous in this case.

iii) if $I = 0$, the interval is light like, in this case the events are connected by a signal ~~which~~ moving with velocity of light

if the events are connected by time like interval there exist an inertial system accessible by Lorentz transformation in which they occur at the same point.

$$\bar{a}^0 = \Gamma(a^0 - \beta a^1)$$

$$\bar{a}^1 = \Gamma(a^1 - \beta a^0)$$

$$\bar{a}^2 = a^2$$

$$\bar{a}^3 = a^3$$

The four vector product is not just the sum of the products of like components rather the zero components have a -ve sign.

~~or~~

$$= -a^0 b^0 + a^1 b^1 + a^2 b^2 + a^3 b^3 \rightarrow \textcircled{A}$$

This is the four dimensional scalar product and it has the same value in all inertial systems. Just ~~as~~ ordinary dot product is invariant under rotation this combination is invariant under Lorentz transformation.

The origin of the -ve sign in 0 zeroth component is the due to presence of covariant ~~or~~ tensor a_μ which differs from the contravariant a^μ is only

in sign

So the

$$a^\mu b_\mu$$

The

are two

$$(x_A^0, x_A^1, x_A^2, x_A^3)$$

The dif

4m

This is

vector.

The ~~is~~ its ~~is~~

is can

i.e.

(4m)

2) Int

here t
separation

The transformation relation representing by ~~e_2^n~~ e_2^n (2) can be expressed as a relation

$$\boxed{x^\mu = \sum_{\nu=0}^3 \Lambda^\mu{}_\nu x^\nu} \quad \text{--- (3)}$$

Λ is Lorentz transformation matrix
 μ even row & ν even column.

The merits of using (3) is that, we can handle the same format in which the relative motion is not along common as $x, \bar{x}$.

The matrix Λ would be more complicated but the structure of e_2^n will remain same.

A four vector is a any set of four components that transform in the same manner as (x^0, x^1, x^2, x^3) under Lorentz transformation.

As shown in e_2^n (3). For the particular case of transformation along x axis any arbitrary four vector may be transformed as follows

Describe the diff. types of carrier transport processes in nanostructure materials.

Following types of Carrier transport may happen in nanoscale material

① Hopping:

→ means the particle has enough Energy to surmount the potential barrier.

• When the size of nanoscale system becomes comparable to characteristic length scale associated w localization of charge carriers within material structure, then the charge carrier can only move between these localized states through hopping

Due to Q confinement eff, the localⁿ of charge carriers can be enhanced in nanoscale sys. which leads to an increase in energy spacing b/w the localized states.

Hence hopping conductivity are made more pronounced.

It contributes to the electrical transport properties of disordered materials.